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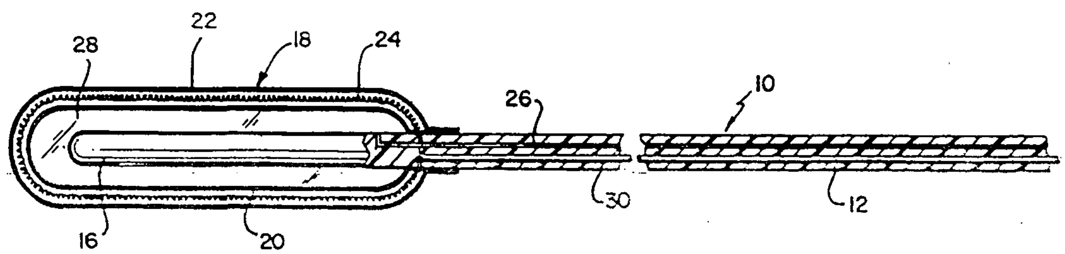
(54) Title: CARDIAC MRI WITH AN INTERNAL RECEIVING COIL AND AN EXTERNAL RECEIVING COIL



(57) Abstract

This invention is a method of imaging the heart or the vessels emanating from the heart with the use of a first magnetic resonance receiving coil (24) and a second magnetic resonance receiving coil (32). The image is obtained by passing the first magnetic resonance coil into the oesophagus. The first magnetic resonance coil is positioned within the oesophagus adjacent the heart and the aortic arch. A first signal is generated from the first magnetic resonance coil. A first image of the heart or the vessels emanating from the heart is generated from the first signal. The second magnetic resonance coil is positioned on the torso proximate to the heart. A second signal is generated from the second magnetic resonance coil. A second image of the heart or the vessels emanating from the heart is generated from the second signal. A combined image of the heart or the vessels emanating from the heart is generated from the combination of the first image and the second image.

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CARDIAC MRI WITH AN INTERNAL RECEIVING COIL AND AN EXTERNAL RECEIVING COIL

This application claims priority pursuant to 35 U.S.C. §119 of Provisional Application Serial No. 60/047,263 filed May 21, 1997, the entire disclosure of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a magnetic resonance imaging (MRI) probe. More specifically, the present invention relates to an apparatus and method for passing an MRI probe (which includes a receiving coil) through either the mouth or the nose, into the esophagus to be positioned adjacent to the heart and/or aorta. This MRI probe may be used with an external MRI receiving coil placed on the patient's chest to provide one combined image of this area of the body from both coils.

2. Discussion of the Related Art

Currently there are over 1.2 million angiography and six hundred thousand angioplasty procedures performed annually in the United States. These procedures are performed to provide an image of the cardiac system. But traditional X-ray angiography and angioplasty only provide a physician with information regarding blood flow, and the amount of an occlusion in the vessel. Moreover, the reasons for an occlusion may not be apparent because no information regarding the

underlying biochemistry of the occlusion is provided by these conventional techniques.

Magnetic resonance imaging is based on the chemistry of the observed tissue. Therefore, MRI provides not only more detailed information of the structures being imaged, but also provides information on the chemistry of the imaged structures. For example, the plaque that causes the blockage in the brain that results in a stroke frequently originates in the aorta. But there are different types of plaque. One type of plaque is very stable and is not likely to cause problems. However, another type of plaque is unstable and can break off from inside the aorta, thereby increasing the risk of stroke. These different types of plaque that are contained within the aorta can be identified by MRI as has been described, for example, by J.F. Toussaint et al., Circulation, Vol. 94, pp. 932-938 (1996). Conventionally, MR imaging of the heart has been achieved with the use of a body coil (i.e., a receiving coil that completely surrounds the torso). However, an external body coil provides a relatively low signal to noise (SNR) when the object to be imaged is the heart (especially the rear portion thereof) and the aorta.

MRI has also become a useful tool to monitor an effective drug therapy. Because MRI does not have the dangerous side effects that are associated with X-rays, it is possible to monitor patients throughout their treatment and adjust their drug regimen as necessary.

MRI is used to pick up a signal of a small object from a relatively large receiving coil. Thus, in producing an MR image, it is desirable to increase the SNR as much as possible. As a general rule, the closer the receiving coil is to the object to be imaged, the better the SNR will be.

SUMMARY OF THE INVENTION

It is an object of the present invention to obtain an MR image having a relatively high SNR. This is accomplished by using a receiving coil that can be passed through the esophagus into a position adjacent to the heart and its surrounding vessels so that an MR image of the heart, the aortic arch and the other vessels emanating from the heart can be taken.

It is a further object of the present invention to obtain a combined MR image having a relatively high SNR from a first receiving coil that can be passed through the esophagus into a position adjacent to the heart and its surrounding vessels and a second receiving coil that is placed on the patient's chest.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view of the MR probe in accordance with the present invention;

Fig. 2 is a partial rear view, with parts broken away of the heart, showing the pericardium and esophagus; and

Fig. 3 is a cross-sectional view of the chest of a human body, showing the heart's pericardial sac, aorta and esophagus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to Fig. 1, an MR probe 10 is illustrated. Probe 10 includes a tube 12 that has a first proximal end 14 and a second distal end 16. The distal end 16 of tube 12 is preferably made of a relatively soft material (e.g., plastic). Distal end 16 is inserted into a balloon assembly 18. Balloon assembly 18 is comprised of an inner balloon 20 and an outer balloon 22. Inner balloon 20 defines an internal chamber 28 that receives the distal end 16 of tube 12. A receiving coil 24 is mounted between the inner balloon 20 and the outer balloon 22. Receiving coils are necessary in MRI apparati to produce an image. Coil 24 may be a known type of device, see, for example, U.S. Patent No. 4,791,372 to Kirk et al. or U.S. Patent No. 4,793,356 to Misic et al., the disclosures of which are hereby incorporated by reference.

Tube 12 includes a fluid conduit 26 that communicates with internal chamber 28. Conduit 26 can be fluidly connected at proximal end 14 to a source of fluid pressure to selectively inflate and deflate the inner balloon as desired. Tube 12 also includes an electronic communication line 30 that electronically connects to receiving coil 24 at distal end 16. Communication line 30 can be electronically connected to a conventional MRI apparatus at proximal end 14 to produce an image based on the signal produced by coil 24. The MRI apparatus can be, for example,

a GE Signa, 1.5 Tesla, which is commercially available from General Electric Company.

An external MRI receiving coil 32 is electronically connected to an electronic communication line 34. External MRI receiving coil 32 may be a known type of device, such as, for example, a quadrature or phased-array coil. The currently preferred external coil is the type described by Fayad et al., An Improved Quadrature Array Coil for MR Cardiac Imaging, JMRI, Volume 2, Number 2, pp. 229-232 (1992), the disclosure of which is hereby incorporated by reference. Communication line 34 can be electronically connected to a conventional MRI apparatus to produce an image base on the signal produced by coil 32. The signals produced by the internal coil 24 and the external coil 32 can each be used to produce an image of the heart and/or the vessels emanating from the heart. These images or signals can be combined by a conventional MRI apparatus to produce a combined image, as one skilled in the art would readily recognize. This combined image has a superior signal to noise ratio and provides a larger coverage area than the image provided from either individual coil.

Roemer et al., The NMR Phased Array, Magnetic Resonance In Medicine 16, pp. 192-225 (1990) and Hayes et al., Noise Correlations in Data Simultaneously Acquired from Multiple Surface Coil Arrays, Magnetic Resonance In Medicine 16, pp. 181-191 (1990) each teach how to combine multiple coil signals to produce one combined image. The disclosure of each of these articles is incorporated herein by reference.

In operation, the balloon assembly 18 is deflated and the outer surface of outer balloon 22 is preferably well lubricated with a conventional, sterile, water-soluble lubricant. The distal end 16 of probe 10 is then inserted either into the mouth or the nose. Of course, if probe 10 is inserted into the nose, the size of the probe should be reduced (e.g., ¼" diameter) accordingly. Distal end 16, which is surrounded by balloon assembly 18, then passes into the esophagus. Tube 12 is continuously inserted into the mouth or nose until the receiving coil 24 is placed in the desired position within the esophagus, as close to the object to be imaged as possible. For the closest approach to the heart and the aortic arch, the receiver coil

24 should be placed within the esophagus behind and under the heart and the aortic arch (See Figs. 2 and 3). The balloon assembly 18 is inflated to maintain the position of receive coil 24 within the esophagus and so that the receiver coil will be at as large a diameter as possible without causing harm to the esophagus. Of course, the amount that the balloon is inflated will vary from patient to patient, but will typically be on the order of about one-half inch in diameter by five inches in length when inflated. The use of receiving coil 24 alone may be sufficient to obtain an adequate image of the aortic arch.

In an in vitro test, the SNR of coil 24 was 30:1 at a radius of six (6) cm and was 15:1 at a radius of seven (7) cm. The prior art whole body coil has a SNR of 20:1 at a location that corresponds to a three (3) cm radius from the position of coil 24 within the esophagus, and a SNR of 10:1 at a location that corresponds to a four (4) cm radius. While the present inventors expect the Fayad et al. external coil 32 to produce better SNRs than a body coil, the internal coil 24 will produce better SNRs when the object is within, for example, a 7 cm radius. Thus, the internal coil 24 will produce a better image of the aortic arch, and the rear portion of the heart (i.e., of objects that are relatively close to it) while the external coil 32 will produce a better image of the front portion of the heart because it is disposed closer to the front portion of the heart. Thus, the signals from the internal coil 24 and the external coil 32 will produce a good quality combined image of the entire heart having a SNR > 20, and preferably a SNR > 30.

The second conventional coil 32 can be disposed on the chest to enhance the images received by coil 24. The MRI apparatus can produce an image from the signal received from coil 24 and a second image from the signal received from coil 32. The MRI apparatus can then combine the images of chest coil 32 and coil 24, which is placed within the esophagus, to produce a more even illuminated combined image of the front and rear portions of the heart and/or its surrounding veins and arteries. Alternatively, the MRI apparatus can produce a combined image from the signals received from coils 24, 32. The combined image has significantly higher SNR than images produced from prior art external receiving coils, including a body coil.

Although preferred forms of the invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that many additions, modifications and substitutions are possible, without departing from the scope and spirit of the invention as defined by the accompanying claims.

WHAT IS CLAIMED IS:

1. A method of imaging the heart or the vessels emanating from the heart with the use of a first magnetic resonance receiving coil and a second magnetic resonance receiving coil, said method comprising the steps of:

passing the first magnetic resonance coil into the esophagus;

positioning the first magnetic resonance coil, within the esophagus, adjacent to the heart and the aortic arch;

generating a first signal from the first magnetic resonance coil;

generating a first image of the heart or the vessels emanating from the heart from the first signal;

positioning the second magnetic resonance coil on the torso proximate to the heart;

generating a second signal from the second magnetic resonance coil;

generating a second image of the heart or the vessels emanating from the heart from the second signal;

generating a combined image of the heart or the vessels emanating from the heart from the combination of the first image and the second image.

2. The method according to claim 1, wherein the first magnetic resonance coil is disposed in a balloon assembly, further comprising the step of:

inflating the balloon assembly to secure the first magnetic resonance coil within the esophagus.

3. The method according to claim 2, wherein the balloon assembly includes an inner balloon and an outer balloon, further comprising the step of:

securing the first magnetic resonance coil between the inner balloon and the outer balloon.

4. The method according to claim 1, wherein the second magnetic resonance coil is positioned on the chest proximate to the heart.

5. The method according to claim 1, wherein a signal to noise ratio of the combined image of the heart is greater than 20:1.

6. The method according to claim 1, wherein a signal to noise ratio of the combined image of the heart is greater than 30:1.

7. A method of imaging the heart or the vessels emanating from the heart with the use of a magnetic resonance probe having a balloon assembly including a receiving coil connected to the probe, said method comprising the steps of:

passing the magnetic resonance probe into the esophagus;

positioning the magnetic resonance probe adjacent to the heart and the aortic arch;

inflating the balloon assembly to secure the probe within the esophagus;

generating a signal from the receiving coil; and

generating an image of the heart or the vessels emanating from the heart from the signal.

8. The method according to claim 7, wherein a signal to noise ratio of the image has a SNR of about 30:1 at a radius of six cm.

9. The method according to claim 7, wherein a signal to noise ratio of the image has a SNR of about 20:1 at a radius of seven cm.

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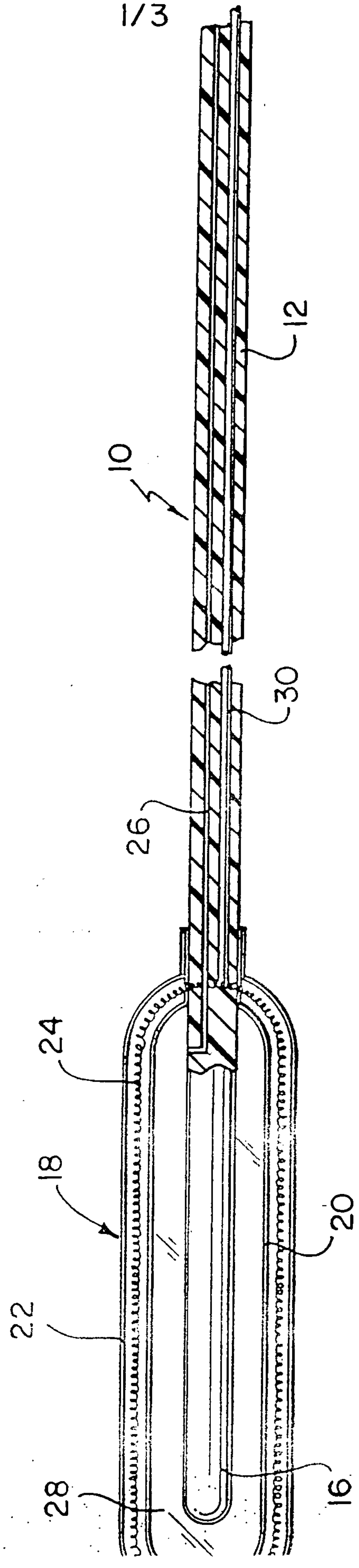


FIG. 1

FIG. 2

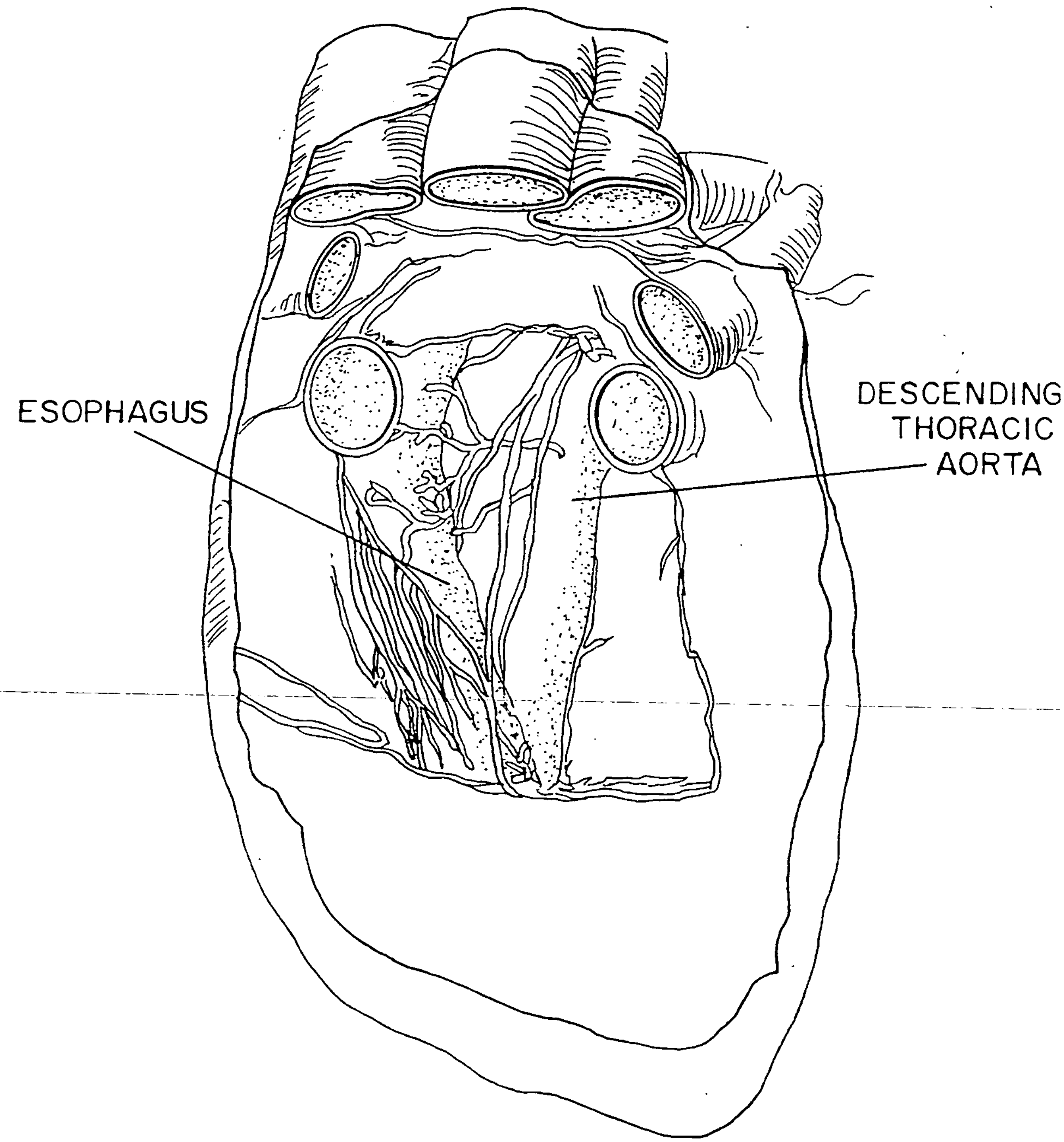
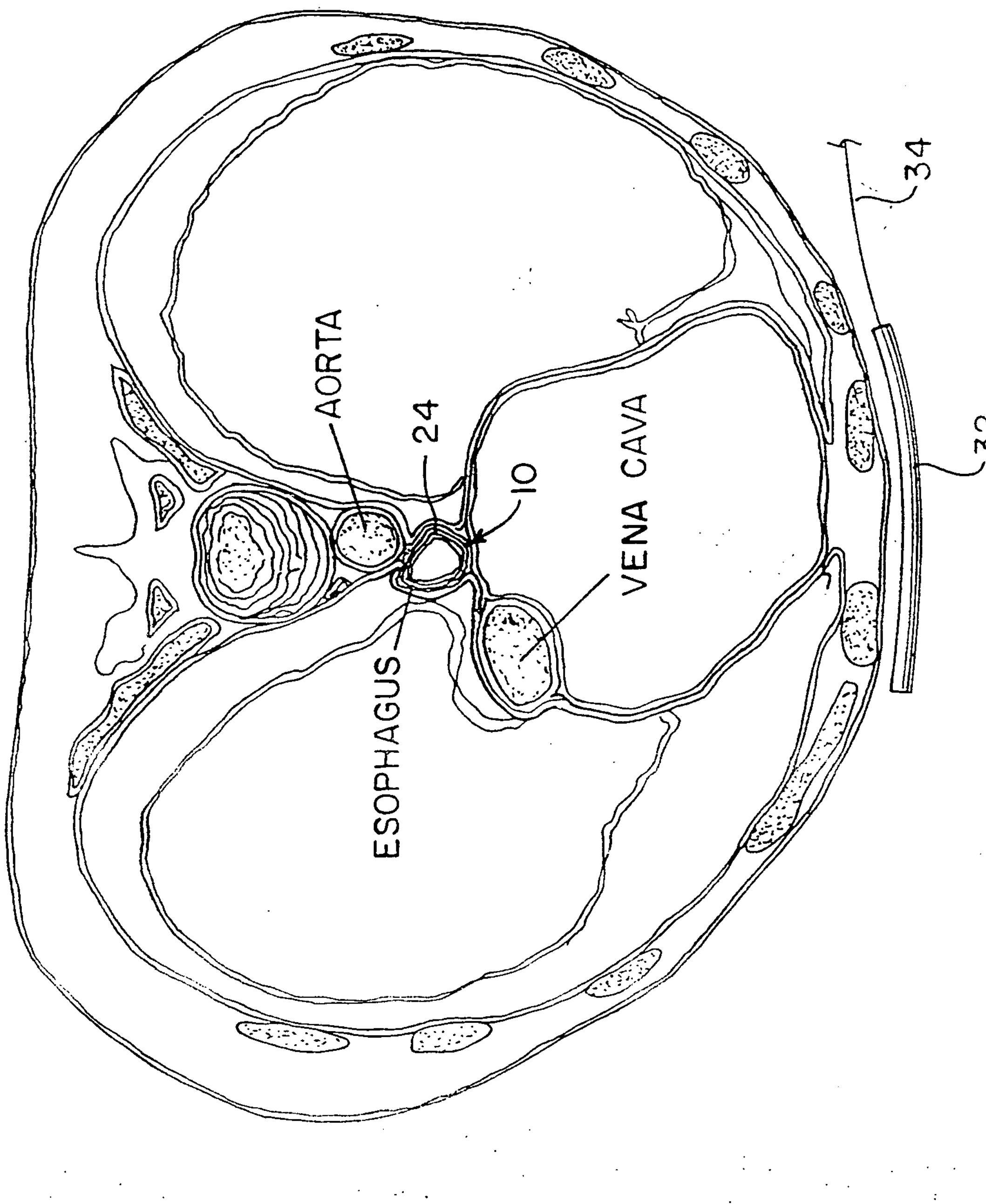


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/10595

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61B 5/00
US CL :128/899; 600/423
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 128/899; 600/373, 374, 381, 423-425

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3,757,773 A (KOLIN) 11 September 1973, Abstract, Figs. 1-9, col. 2 line 25 to col. 3 line 6, and col. 4 lines 38-54.	1-4, 7
Y	US 5,476,095 A (SCHNALL et al.) 10 December 1995, Abstract, Figs. 1-11, col. 2 lines 10-51, and claims 1-29.	1-4, 7
Y	US 5,307,814 A (KRESSEL et al.) 03 May 1994, Abstract, and Figs. 1-11.	1-4, 7
Y	US 5,402,788 A (FUJIO et al.) 4 April 1995, Abstract, Figs. 1-21, col. 1 line 65 to col. 2 line 36, col. 9 lines 33-45, and claims 1-17.	1-4, 7
A	US 5,413,104 A (BUIJS et al.) 9 May 1995, Abstract, Figs. 1-5, and claims 1-4.	1-9

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,447,156 A (DUMOULIN et al.) 05 September 1995, Abstract, Figs. 1-6, and claims 1-4.	1-9